

NUMERICAL INVESTIGATION ON  
STEEL – CONCRETE COMPOSITE SLABS  
UNDER BLAST LOADING

AMININ FAQIH BIN MOHD AMIN

B. ENG(HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG



## **STUDENT'S DECLARATION**

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

---

(Student's Signature)

Full Name : AMININ FAQIH BIN MOHD AMIN

ID Number : AA15165

Date : 31<sup>ST</sup> MAY 2019

NUMERICAL INVESTIGATION ON  
STEEL – CONCRETE COMPOSITE SLABS  
UNDER BLAST LOADING

AMININ FAQIH BIN MOHD AMIN

Thesis submitted in partial fulfillment of the requirements  
for the award of the  
B. Eng (Hons.) Civil Engineering

Faculty of Civil Engineering & Earth Resources  
UNIVERSITI MALAYSIA PAHANG

MAY 2019

## **ACKNOWLEDGEMENTS**

I would like to express my deep and sincere gratitude to my supervisor, Dr Aizat Bin Alias for his invaluable guidance, continuous encouragement and constant support in making this research possible. I really appreciate his guidance from initial to the final level that enable me to develop an understanding of this research thoroughly. Without his advice and assistance, it would be a lot tougher to complete this research.

I acknowledge my sincere indebtedness and gratitude to my parents and my siblings for their love, support, prayers and sacrifices throughout my life. To all my course mates and friends, thanks for the memory and friendship. Lastly, to any person who contributes to my final project direct or indirectly, I like to acknowledge their supports, which was helping me a lot to successfully complete this research. Thank you.

## **ABSTRACT**

This paper discusses the numerical investigation on steel – concrete composite slabs under blast loading. The study was conducted using finite element software and the finite element model of the steel – concrete composite slabs was validated against a disparate test data. The model was used to investigate key parameter in particular; the diameter of mesh reinforcement used in the steel – concrete composite slabs. The validation results show that the computed model of steel – concrete composite slabs can almost replicate the result from the experimental. Thus, the model that have been computed was extended for blast simulation using CONWEP. CONWEP is a blast load function available in Abaqus FEA. The blast-profiles from the CONWEP was verified against the result obtained from a disparate field test. The results suggest the CONWEP is able to simulate the blast-pressure profiles with sufficient accuracy. By using CONWEP in Abaqus, the validate composite slabs were subjected to various blast loading cases. From the study, it was found that the pressure is affected by the stand-off distance and the weight of the mass explosive. Which the higher the explosive mass and the shorter standoff distance used will produce high impulse. High impulse load resulted a higher displacement on the steel – concrete composite slabs. Finally, from the parametric study, the limit diameter mesh reinforcement to use in steel – concrete composite slabs is 8 mm because increasing it more will not give significant resistance toward blast load.

## ABSTRAK

Kertas kerja ini membincangkan tentang kaji selidik mengenai lantai komposit keluli – konkrit apabila terkena bebanan letupan. Kajian ini telah dijalankan menggunakan perisian komputer Abaqus. Model lantai komposit keluli – konkrit yang direka melalui perisian komputer ini telah disahkan melalui beberapa pengesahan data daripada ujian-ujian yang berbeza. Model yang sama juga telah digunakan untuk mengkaji parameter yang lain seperti kesan penukaran saiz diameter tulang kerangka yang digunakan dalam struktur lantai komposit ini. Hasil keputusan telah mengesahkan bahawa model yang komputer yang direka mampu menghasilkan keputusan ujian yang hampir sama dengan hasil keputusan ujian daripada ujikaji eksperimen. Oleh itu, model ini akan dilanjutkan lagi untuk ujian simulasi letupan menggunakan fungsi “CONWEP” yang tersedia di dalam perisian Abaqus. Sebelum itu, satu pengesahan lain telah juga dilakukan, iaitu simulasi ujian letupan ke atas rasuk keluli yang berdasarkan dari kesusasteraan yang lain. Dari pengesahan itu, satu kesimpulan dibuat bahawa tekanan dari letupan dipengaruhi oleh jarak dan berat bahan letupan. Ini bermakna, lebih tinggi jisim bahan letupan dan jarak antara tempat letupan dan struktur pula adalah pendek, maka satu bebanan yang tinggi akan terhasil. Dari simulasi yang dilakukan, bebanan yang tinggi akan menyebabkan kerosakan yang tinggi. Akhir sekali, dari kajian parameter yang telah diadakan, saiz diameter maksima yang disyorkan untuk tulang kerangka untuk digunakan adalah 8 mm. Hal ini kerana, jika saiz diameter lebih tinggi digunakan, ianya tidak akan memberi kesan yang signifikan terhadap rintangan daripada bebanan letupan.

## **TABLE OF CONTENT**

**DECLARATION**

**TITLE PAGE**

**ACKNOWLEDGEMENTS** **6**

**ABSTRAct** **7**

**ABSTRAk** **8**

**TABLE OF CONTENT** **9**

**LIST OF TABLES** **11**

**LIST OF FIGURES** **12**

**CHAPTER 1 INTRODUCTION** **13**

1.1 Introduction 13

1.2 Statement of Problem 14

1.3 Objective of Study 14

1.4 Significance of Study 15

**CHAPTER 2 LITERATURE REVIEW** **16**

2.1 Composite Structure 16

2.2 Blast Waves and Blast Loading 20

2.2.1 Important Blast Wave Parameters 21

2.2.2 Blast Wave External Loading on Structure 23

2.2.3 Blast Loading Analysis 24

**CHAPTER 3 METHODOLOGY** **26**

3.1 Introduction 26

3.2	Project Planning	26
3.3	Data Collection	27
3.3.1	Static Test	27
3.3.2	Blast Test	30
3.4	Modelling	33
3.4.1	Material Properties	33
3.4.2	Assembled	34
3.4.3	Boundary Condition	36
<b>CHAPTER 4 RESULTS AND DISCUSSION</b>		<b>37</b>
4.1	Introduction	37
4.2	Validation	37
4.3	Blast Load Test	42
4.4	Parametric Study	46
<b>CHAPTER 5 CONCLUSION AND RECOMMENDATION</b>		<b>48</b>
5.1	Conclusion	48
5.2	Recommendation	49
<b>REFERENCES</b>		<b>50</b>



## **LIST OF TABLES**

Table 1: Details of Shorter Shear Span Loading and Its Behaviour	28
Table 2: Different Combinations of Stand -Off and Charge Weight	32
Table 3: Stand-Off Distance of Pressure Transducers	33
Table 4: Comparison Of Maximum Load For Static Test	40
Table 5: Cases for The Blast Test and The Result of Maximum Displacement (m)	44
Table 6: List of Diameter of Mesh Reinforcement	46

## **LIST OF FIGURES**

Figure 1: Composite Deck Slabs Using Different Types of Profiled Sheets	17
Figure 2: Schematic View of The Experimental Setup	17
Figure 3: Deformed frame view for (a) one column loss analysis (b) non-linear dynamic analysis (c) five column loss analysis	20
Figure 4: Blast Wave Pressure - Time Profile	22
Figure 5: Blast Wave Parameters for Spherical Charge of TNT	23
Figure 6: Load Vs Central Deflection for Shorter Shear Span Specimens.	29
Figure 7: Schematic View of The Supporting Arrangements.	30
Figure 8: Cross Section of The Test Specimens (dimensions are in milimeters)	31
Figure 9: The Schematic View of Charge Location	31
Figure 10: The Dimensions of The Test Frame and The Reflecting Surface	32
Figure 11: The Typical Reflec Structure to Resist The Effects of Accidental Explosions ted Pressure for Blast Shot: (A) Shot 1 (B)Shot 2	33
Figure 12: The Composite Deck Slabs for Static Test	35
Figure 13: The Steel Beam Model Subjected to Blast Load	36
Figure 14: Different Mesh Result	38
Figure 15: Static Test Comparison for Experimental and Numerical Analysis Result	39
Figure 16: General View the Response of Structure After Subjected to Static Loads	40
Figure 17: Comparison Result for Steel Beam Subjected to Blast Load for Experimental and Numerical Analysis	41
Figure 18: General View of Steel Beam Subjected to Blast Load	42
Figure 19: Computed Model for Blast Test for Steel - Concrete Composite Slabs	43
Figure 20: Relationship of The Blast Impulse and The Maximum Displacement of Composite Deck Slabs	45
Figure 21: Displacement - Time Graph for Case 1-4	46
Figure 22: Result from Parameter Study of Mesh Reinforcement	47

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Introduction**

Steel – concrete composite slabs means that there are at least two components of the structure such as the steel deck and reinforced concrete floor that is bonding together by any mechanical techniques and act compositely to resist the tension and compression of the structure when subjected to any loads. Other than that, this type of structure can give advantages when comes to faster flooring construction, lighter floors and the rational use of construction materials (Marimuthu V., Seetharaman S., et al., 2006). Thus because of all that, this structure is becoming more popular in nowadays construction industry.

As it becomes common in buildings, researchers are interested to investigate the behaviour of the structures to blast loads because of the threats from terrorist attacks are ever increasing. Recently, Sri Lanka, had experienced three bombing incidents that resulted in more than 300 casualties and severe damages to buildings. Therefore, it is evident there is a need to investigate the response of the composite structure such as steel-concrete composite slabs to improve the understanding of the behaviour of the structure when subjected to blast loading.

Other evident is when Jintao Li and others (Jintao Li., Chao Huang, et al., 2018) conducted detailed finite element analysis of composite bridge deck to study the behaviour of structure under blast loading. The result suggested that the damage modes of the structure are depend to the type of the loading subjected which the high impacts loads are difference with blast loads. Thus, to ensure the safety of these structures

especially for construction of blast-risk structures such as embassy buildings, it is important to design them which can withstand the expected design-based threat level.

## **1.2 Statement of Problem**

There is no literature can be found for the steel – concrete composite slabs subjected to the blast loading. Most of them, focussed on the experimental of the steel – concrete composite slabs under high impacts loading rather than the blast loading. For example, an experimental study has been carried out to investigate primarily the shear bond behaviour of the embossed composite deck slabs under simulated imposed loads, from paper by Marimuthu, Seetharaman, et al. (Marimuthu V., Seetharaman S., et al., 2006) and behaviour of headed shear stud in composite beams with profiled metal decking from paper by Qureshi and Lam (Qureshi J. and Lam D., 2012). This is because the experimental on the blast loading is too costly and high risk.

As the alternative to experimental methods, the numerical model can be performed using finite element software such as Abaqus FEA. This method can quantitatively stimulate the mechanical character of the steel – concrete composite slabs subjected to blast loading in more flexible and cheaper way. By utilise the finite element analysis, the understanding on the performance and response this structure under blast load can be enhance. Furthermore, parametric study can also perform to study the effect of that parameters to help improve the blast resistance design consideration for this structure in the future.

## **1.3 Objective of Study**

In general, the objectives of the study are;

- a) To model steel-concrete composite profiled slab using Abaqus FEA software and validate the model against test data.
- b) To study behaviour of steel-concrete composite slabs under the blast loading.
- c) To study the influence of reinforcement mesh diameters on the behaviour of the steel-concrete composite slabs subjected to blast load.

#### **1.4 Significance of Study**

This paper studies about the response behaviour of steel – concrete composite slabs under blast load. Thus, from that result and data from the numerical analysis of the structure, we can develop some awareness of the hazards and risks created by the blast loads. For future use, this paper can help in other researchers to implement the blast resistance design of the structure especially in steel – concrete composite slabs to prevent structure failure.

## REFERENCES

- Alashker Y., El Tawil S., et al, 2010. Progressive Collapse Resistance of Steel-Concrete.
- Jintao Li., Chao Huang, et al., 2018. Numerical investigation of composite laminate subjected to combined.
- Lawver D., D. R. e. a., 2003. Simulating The Response of Composite Reinforced Floor Slabs Subjected to Blast Loading.
- Marimuthu V., Seetharaman S., et al., 2006. Experimental studies on composite deck slabs to determine the shear-bond.
- Nassr A., G. R. A. e. a., 2012. Experimental Performance of Steel Beam under Blast Loading.
- P. D. Smith and J. G. Hetherington, 1994. *Blast and Ballistic Loading of Structures*. s.l.:Routledge.
- Polak, A. S. G. a. M. A., 2015. Finite Element Analysis of Punching Shear of Concrete Slabs.
- Qureshi J. and Lam D., 2012. Behaviour of Headed Shear Stud in Composite Beams. *Advances in Structural Engineering*, Volume 15.
- Rao, A. M. a. C. L., 2016. Failure analysis of V-shaped plates under blast loading.
- S. Jeyarajan, J. Y. R. L. a. C. G. K., 2015. Analysis of Steel - Concrete Composite Buildings for Blast Induced Progressive Collapse.
- Unified Facilities Criteria (UFC), 2008. *Structure to Resist The Effects of Accidental Explosions*. s.l.:s.n.

(Harvard System) for your references